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NOTES ON THE SURFACE GEOLOGY OF EASTERN MASSACHUSETTS.

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THE prevalent line of strike in Massachusetts, as is well known, is north and south, and in the western half of the State there are no exceptions of importance to be noted. East of the Nashua Valley, however, a northeast and southwest strike prevails, especially in Essex and Middlesex counties; a comparatively limited area in the southeastern part of Worcester County exhibits a strike at right angles to this, or northwest and southeast; while among the Primordial and Carboniferous strata, a nearly east and west strike is most common.

"Geology is revealed in topography," and these fundamental structure lines find distinct expression in the leading topographic features of the State. In the Connecticut Valley and Berkshire County, where the geologic structure is simplest, this correspondence between geology and geography is most marked, and is observable not only in the grander features, — such as the Taconic and Hoosac ranges of mountains, and the Housatonic and Connecticut rivers, — but may also be readily traced in the courses of most of the minor streams and subordinate surface reliefs. East of the Wachusett range of highlands, we find, with greater complexity of geologic structure, two general topographic trends. The more prominent of these shows a close conformity with the prevalent strike, — northeast and southwest, varying toward east and west; while the other coincides with the transverse strike and the known direction of glacial movement.

Water and ice are the principal agents by which the topography of this region has been fashioned. Now there is little room to doubt that the sculpturing done by water exhibits, on

the whole, a closer correspondence with geology than the reliefs shaped by the action of ice. This results from the essential unlikeness in modes of action of the agents in question. The topographic work done by rivers is effected mainly through degradation.

> "Time but the impression deeper makes,
> As streams their channels deeper wear."

The rivers of this section seldom deposit much material along their courses, and the detritus delivered at their mouths is usually transported to a greater or less distance, and finally laid down by the sea; so that this process, although the opposite of degrading, is more marine than fluvial. The action of the sea in modifying the contour of the land, on the contrary, is, generally speaking, twofold: degradation, which, when the waves work upon rocky shores, is determined more or less in direction and amount by the geologic structure of the degraded land; and building up, which operates by the transportation of loose materials and their accumulation at particular points, and depends mainly upon the direction and force of ocean currents, tidal waves, and prevailing winds, and upon the general shape of the land and ocean bed, though quite independent of their geological constitution, except mediately in so far as this has determined their form. In this region, such features as the outer end of Cape Cod, portions of Nantucket, the southeastern part of Martha's Vineyard, part of the coast of Essex County north of Cape Ann, and Lynn, Nantasket, and Duxbury beaches appear to be due to the constructive action of the sea; and of course they can be expected to conform in trend only imperfectly, if at all, with the features produced by degradation. The close correspondence between their forms and structure usually observable in those topographic details fashioned by the degrading action of the sea or rivers is, no doubt, largely due to the mobility of the water. It is by virtue of this wonderful property that the ocean possesses a power of discrimination, — a sort of tactual sense, as it were, — which enables it to act differently upon rocks having unlike constitutions, and thus, in effect, to dissect a rocky coast in a manner analogous to the unlocking of the molecular structure of a mass of ice by a transmitted beam of light. In striking contrast with this is the action of a large land glacier, such as exists at present in Greenland and Antarctic Land, and probably spread over New England at the time when the phenomena — drift and striated

and polished rock surfaces — commonly ascribed to glaciation were produced. The comparative immobility of a large glacier causes it to move almost as a unit, and, "strong in solid singleness," it can be swerved by none but the largest reliefs, especially in a region of gentle slopes and low altitudes like Southeastern New England. So that generally, only in so far as the fashioning of these reliefs has been determined by their structure can the progress of the ice-cap be regarded as influenced by the geological constitution of the land over which it moves. Hence we are led to conclude that surface lineaments resulting from a wide-spread glaciation will exhibit great uniformity of trend over wide regions, and a general independence of the structure of the subjacent rocks; and such is conspicuously the fact in Eastern Massachusetts.

There are perhaps no surface features which are more clearly the product of glaciation than the lakes and ponds found, and as a rule found only, in glaciated regions, and which abound in New England. The great extent to which regions which have been subjected to the action of an ice-sheet are distinguished by the presence of lake basins becomes more apparent when we reflect that, as has been pointed out by Professor N. S. Shaler, these basins are probably much fewer and smaller now than when first formed at the close of the glacial epoch; for "there are in operation in the regions characterized by glacial lakes no forces capable of producing such depressions; on the contrary, all the forces at present in action tend to obliterate the existing basins." Professor Shaler has called attention also to the facts that these lake basins seldom, "except the smallest, present any approximation to a circular figure;" and that "the major axis has usually a north and south trend." The following data (derived from approximate measurements, made on good maps, of the ponds and lakes of Eastern Massachusetts) show, among other things, how general is this elongation in a north and south direction. Two hundred and ten basins were measured, including all but the very smallest, in that portion of the State east of Worcester. The mean direction of all the major axes is about N. 5° W. The mean ratios of the major axes to the minor axes is 2.5; that is, the ponds are, on an average, two and one half times as long as broad. The average trend of the longer diameters, it will be observed, coincides very closely with the mean direction of the glacial striæ of this region, and the courses traversed by erratics. In only thirty of the two hundred

and ten basins measured does the direction of the major diameter vary more than forty-five degrees from the general average, N. 5° W.; while ninety, or nearly one half the whole, deviate less than ten degrees from it, and only thirteen are found falling within ten degrees of a direction at right angles to the mean, or N. 85° E. The mean ratio of the major to the minor diameters for these ninety ponds is 2.4; but for the thirteen it is only 2. The extreme range of the glacial striæ of Eastern Massachusetts, according to Professor Edward Hitchcock, is from N. 5° E. to N. 55° W., — sixty degrees; and it is found, on examination, that the courses of fully two thirds of the ponds lie within these limits.

Terminal moraines appear to have been formed at very infrequent intervals in this region; the Elizabeth Islands, however, constitute a fine example of such a moraine, rendered conspicuous by its isolation; and others are known to exist inland. Wherever occurring, they must, of necessity, have approximately east and west trends, and bodies of water bordered by them will share the same course. In this way I conceive we may account for some of the extreme deviations from the mean trend observed among the lake basins. This explanation fails in many cases and yet these offer no special difficulty, for a more detailed consideration of our data shows a slight dependence of the phenomena in question on the general plan of the geologic structure of the region. Thus, in Essex, Middlesex, Norfolk, and Bristol counties, and all but the southeastern part of Plymouth County, where the predominant strikes among the rocks are east and west and northeast and southwest, we find the average relative dimensions of the ponds expressed by the number 2.3: while in the eastern half of Worcester County, where the prevailing strikes range from north and south to northwest and southeast, that is, are generally parallel with the line of march of the ice-sheet, the ratio of the average length to the average breadth has the comparatively high value of 3.15. Hence, we see that, while the lacustrine depressions are, as a nearly universal rule, elongated in the direction of glacial movement, the amount of this elongation is sensibly less where the progress of the ice-cap was transverse to the general strike of the underlying rocks than where it coincided with the strike. Another fact brought out by a comparison of these data has the same significance, namely: the deviations from the mean trend of the basins are fewer and smaller where the direction of the glacial motion

coincides with the strike of the rocks than where it is transverse to the strike. Thus, in Essex and Middlesex counties the trends of one half the ponds deviate more than twenty degrees from the mean, while in Worcester County the proportion is only one fourth.

One of the most remarkable facts in the distribution of glacial detritus, or drift, in Massachusetts is the comparatively great depth to which it has been accumulated over the southeastern portion of the State. There is a marked paucity of rock outcrops in the southern half of Plymouth County; south of Plymouth and east of Middleborough they are rarely met with; and Barnstable County is absolutely destitute of them. It is not improbable that the solid rocks in this region are so deeply buried by the unconsolidated superficial deposits that if the latter were removed, the whole of Barnstable County and a considerable part of Plymouth County would be invaded and covered by the sea. Professor Edward Hitchcock, in discussing this subject, estimated the maximum depth of the drift in this region at not less than three hundred feet; and he evidently believed it to exceed this. Certainly here, if anywhere, we may expect lake basins and river valleys to exhibit in their forms and trends a complete independence of the underlying rocks. This expectation is justified by the facts. There is not in the region under consideration a stream of any considerable size that has not a north and south course, although the strike of the underlying rocks undoubtedly approximates east and west. As a result of this parallelism of the water-courses, we find no streams of any importance cutting the north and south coast-lines; the western shore of Cape Cod Bay between Elisha's Point and Scusset Harbor is almost unbroken by debouching streams, and Buzzards Bay receives not a single tributary from its eastern shore. Coast-lines transverse to the direction of glacial action, on the contrary, are fretted with river mouths and long, fiord-like bays and inlets, as the northern shore of Buzzards Bay and the southern coast of Falmouth. The evidence from the lake basins is almost as unequivocal as that from the rivers. Measurements of all but the smallest basins between Orleans and a curved line extending from Kingston southerly to the mouth of Wareham River, convex to the west and including Simpson's Pond, give north and south as the average trend or direction of the major diameters, and 2.7 as the ratio of the length to the breadth, or the mean elongation.

A comparison of the lacustrine depressions of this region of excessive drift with those of Worcester County, on the one hand, and of Essex, Middlesex, Norfolk, Bristol, and Northern Plymouth counties, on the other, shows that the value of the mean elongation in the former district, 2.7, is intermediate between the values of the same property in the two latter, 3.15 and 2.3, respectively. And thus we are brought to the following general conclusion: where the drift is so deep that the forms of the lake basins have no necessary relation with the subjacent rocks the mean elongation of the depressions is greater than in districts where, the detrital sheet being thinner and less universal, the basins are partially rock-bordered, — when the progress of the ice-cap was transverse to the general strike or structure lines of the rocks, — and less when this movement coincided with the strike.

The reliefs of this region are, for the most part, of very moderate altitude; and, in consequence of the sharper contrast between land and water than between hill and valley, they are seldom represented on maps with even an approximation to the accuracy characterizing the delineation of water-bordered contours. Hence it were futile to attempt to discuss our hills and ridges in the same manner as the lake basins and river valleys. Fortunately, however, the general facts are so plain that they do not require this for their elucidation. It is in the experience of most observers in this region, that the drift hills have usually a lenticular outline, are more or less ridge-like, and that both hills and ridges coincide in trend with the direction of glacial movement. Those remarkable drift ridges in Essex County, described by Mr. G. F. Wright, and extending with a nearly rectilinear course from beyond the New Hampshire boundary to Massachusetts Bay, exemplify in a striking manner the form, trend, and general independence of geology characterizing our drift topography. Elevations composed mainly of rock *in situ*, on the contrary, express in their forms and trends the leading geologic structure lines of the region, but do not admit of correlation with the course of glacial action. The Wachusett range of highlands, the parallel range forming the eastern rim of the Nashua valley, the somewhat irregular belt of hills extending from Cape Ann to Beverly, the well-known range sweeping with a bold front from Swampscott to Waltham, and the Blue Hill range in Milton and Quincy are good examples of the more prominent and general of our rock reliefs. The first

two are fashioned from stratified rocks, and are more regular and distinct than the others, which are for the most part composed of unstratified rocks. Yet the latter, no less than the former, reveal the structure of the rocks composing them; for exotic rocks, being, in a certain sense, structureless, only conform with the general law in giving rise to a systemless topography.

The notion appears to be gaining ground among geologists that the power of a continental glacier to degrade the surfaces over which it moves, or, at least, to alter the forms of those surfaces, has been greatly over-estimated. It has become unnecessary, in the light of recent investigations, to ascribe to the active agent of the drift epoch, whether land-ice or icebergs, great abrading power in order to account for the formation of the truly immense and generally chaotic mass of superficial detritus constituting the drift; for in the subaerial decomposition of rocks, especially crystallines, *in situ*, during immense periods of time, we have a process fully competent for the production, both in quantity and quality, of the detrital materials, including bowlders, found in glaciated regions. The real degradation, the formation of the detritus, is mainly the work of chemical and not of mechanical forces. The sheet, usually thirty to forty, sometimes fifty, and even one hundred feet in thickness, of thoroughly decomposed materials passing insensibly into solid rock below, found over a large portion of the Southern States, and occurring generally wherever there are crystalline rocks in low latitudes, is a substantial monument to the degrading power of these silent agents, which are doubtless still in operation. As a nearly universal rule, we find the drift in New England reposing upon smooth and polished surfaces of undecomposed rocks, which evinces that the glaciating agent had sufficient erosive power to sweep away all traces of the zone of partially decomposed, semi-rock-like material that in the South intervenes between the firm rocks below and their decomposed skeleton above, and which probably existed over glacial latitudes in preglacial times. The theory of subaerial decomposition so far diminishes the erosive power required, by previous hypotheses, in the agent of glaciation as to render possible a reconciliation of the existence of an ice-cap in quite recent geologic time with the well-known fact that many reliefs of comparatively small magnitude have trends and contours wholly at variance with the courses of glacial movement, and incompatible with the supposition that the ice-sheet moved as a rigid, unyielding rasp, removing hundreds of feet of solid rock from the surface of the country.

It appears probable that but few of those surface unevenesses which are impressed upon the rocks have had a glacial origin. At any rate, a large number, including all the more important, of these rock-impressed inequalities of the surface in this region are doubtless much older than the glacial epoch which has but recently passed away, and, if due to glaciation at all, were sculptured during some earlier reign of ice. Such large rivers as the Merrimac, Nashua, and Blackstone are unquestionably of preglacial origin. Their courses are parallel with the strikes of the rocks over which they flow; and the first two, at least, occupy well-marked geological valleys. Furthermore, it is hardly conceivable that glaciation can have been the cause of rock-bordered valleys transverse to its line of action, as is the Merrimac in Massachusetts; and the valley of this stream, so far from being the product of glaciation, probably exists in spite of the tendency of the ice-cap to obliterate it.

The question, also, as to what extent the so-called fiords of this region are due to the excavatory power of ice during the last glacial period can hardly be regarded as settled. Reference is made, of course, only to fiords carved from the solid rock, which is not the case with those in Barnstable County. The fact that these inlets are chiefly found on coasts transverse to the direction of glacial movement becomes, I think, less an obstacle to the denial of their glacial origin, when we reflect that the tendency of an ice-cap would be to fill up and obliterate such coastal inequalities as were transverse to its line of progress, and at the same time to clean out such as coincided with its march. If the superficial deposits were removed from the New Hampshire coast, the northeastern part of Essex County, and Eastern Plymouth County, it is not impróbable that these north and south shores would present irregularities nearly as marked as those that indent our southern coast.

It is a significant fact that the northern shore of Massachusetts Bay, though parallel with the northern shore of Buzzard's Bay, and hence similarly related to the course of glacial action, is destitute of conspicuous indentations that can be regarded as the work of the ice-sheet; for all the important rock-bordered deflections of this coast-line have their major axes transverse to the line of march of the glacier. Marblehead harbor is one of these northeast and southwest troughs; and here we have evidence of a unique and conclusive character, proving beyond question its preglacial origin. This strait — for such it would be

but for the bar across its southwestern end — is a well-marked depression, and has clearly been formed by the erosion of the ancient Huronian granite, petrosilex, and diorite, by which it is bordered. Near the middle of the southwest side of the harbor, visible only at low tide, is a hard, whitish, fine-grained sandstone or arenaceous slate. It overlies unconformably the banded petrosilex found on this shore: the petrosilex dips steeply to the southeast, while the sandstone has apparently, a gentle dip in the opposite direction. Interposed between the petrosilex and sandstone is a thin stratum of conglomerate, composed of pebbles of the former. Obviously, Marblehead harbor was excavated before the deposition of this sandstone, which can hardly be newer than the Carboniferous period, and is probably coeval with the Primordial rocks in the vicinity of Boston. Other remnants of the sandstone are scattered over Marblehead neck, in such positions as to indicate that the granite and petrosilex of which the neck is mainly composed have suffered but little erosion since the formation of the sandstone. The removal of the sand-rock from the harbor, which it doubtless once filled, may have been the work of ice in recent geologic times; but the harbor itself must have had substantially its present form before the close of the Palæozoic era. Salem, Beverly, Manchester, and Gloucester harbors have also been cut out of Huronian or still older rocks; and, when we consider their striking resemblance in form and trend to Marblehead harbor, it is difficult to avoid the conclusion that they have an antiquity equally great.

The limitation of fiords to high latitudes and to coasts favored with an abundant precipitation of moisture (usually western coasts), that is, to coasts most favorable for the formation and development of glaciers, certainly appears a sufficient warrant for the commonly accepted opinion that these deep, narrow, and ofttimes tortuous channels are the product of glacial erosion, the more especially since fiord valleys usually exhibit, in the form of moraines and striated and polished rock surfaces, unmistakable traces of the former presence of glaciers, and in some regions are occupied by existing ice streams. Yet this theory fails most signally to adapt itself to some phenomena of an important and general nature. Mr. James Geike, in The Great Ice Age, says that some of the fiords of Great Britain are known to date back to the Devonian age, and that, though many may have been deepened by ice action during the last and earlier glacial epochs, they were *all originated by streams and rivers in*

ages long anterior to the Post-Tertiary ice time. Valleys must precede valley-eroding glaciers.

From our remote northwestern coast we have yet more conclusive testimony to the preglacial origin of the phenomena in question. In no region, save perhaps the western coast of Norway, is there a grander development of fiords than on the Pacific coast of North America, from the labyrinth of Vancouver Island northward. These fiords are cut in the seaward slope of a bold mountain range, bearing the lofty peaks of Fairweather and St. Elias. According to Mr. W. H. Dall, almost every fiord of considerable size on this coast, especially toward the north, "has at its head a glacier, or the remains of one. Some of these glaciers are of extraordinary size and grandeur." The same authority states that evidence is wholly wanting that these glaciers ever much exceeded their present limits. The walls of the fiords, short distances below the present terminations of the glaciers, are not smoothed or striated; and no terminal moraines stretch across the fiords, or form shoals at their mouths. These are typical fiords, and yet the evidence that they are not due to the action of ice in any recent geologic time is rendered conclusive by the occurrence in some of the fiords having glaciers at their sources, according to Mr. Dall, of islands composed of soft and yielding Tertiary strata, which must have been completely swept away had the ice streams ever filled the gorge. The existence of these Tertiary beds is a certain indication that the fiords antedate that period, and hence they are, in a certain sense, the cause rather than the consequence of the present ice streams.

The tendency of the considerations here presented is evidently toward the view that, comparatively speaking, the ice-cap rested lightly upon the land, and that the topographic features having a skeleton or frame-work of rock are, as a rule, of preglacial origin. In other words, it appears probable that if the present mantle of drift were entirely removed from the face of the country, leaving a surface of naked rock, we should have in all important respects a restoration of the anteglacial contours. And this ancient topography having been, as I conceive, fashioned mainly by agents more subtle than an ice-cap, and hence taking a deeper hold on geologic structure, would if thus undisguised reveal a closer correspondence with the structure lines of the subjacent rocks than we are able to detect in the existing hills and valleys considered as a whole.

The uniformity of trend in glacial striæ and drift transportation observable over wide regions appears inconsistent, at first view, with the supposition that the ice-cap had but little erosive power: a contradiction seems implied in the possession by a glacier of a magnitude and rigidity which enabled it to move without deviation over prominent reliefs, and a general inability to erode those reliefs. How can we harmonize the lightness of its tread with its rectilinear march over uneven surfaces? That ice in glacier masses behaves essentially as a very viscous liquid is well known; and a solution of the problem is found in a peculiar condition, pointed out by many writers, and necessarily existing in a continental glacier, which limits the freedom of motion among themselves, possessed by the different portions of the ice-sheet, to a vertical direction. Lateral deviation is rendered impossible by the inferior plasticity of the ice; and hence, when any portion of the ice-sheet encounters an obstacle, around which it would flow if sufficiently fluent, it is found easier to overcome the gravity of a small mass of ice than the cohesion of a relatively large mass, and the ice, moving in the direction of least resistance, passes in a vertical plane over the obstruction.

PSEUDIS, "THE PARADOXICAL FROG."

BY S. W. GARMAN.

PSEUDIS is a peculiar South American frog, peculiar in the fact that it grows smaller as it becomes adult, and in possessing a nearer approach to a thumb than any of its relatives. It is much to be doubted whether there is anything in the actual history of an individual belonging to this genus that calls for an amount of notoriety to which the most common toad or frog may not aspire. To be sure, the tail is kept long after all the legs appear; the tadpole is larger than the adult, and the creature has a hand in which the thumb is opposed to the three fingers, yet all these are hardly enough to demand the amount of attention of a certain kind which the genus has received. In fact, as often happens in the case of men, Pseudis owes much of his reputation to a mistaken estimate. If we might trace him from as early a period as men have seen until well advanced in life, we should probably see nothing more than takes place in the history of all batrachians. We might meet the egg first coming within the limits of our vision as a round, granule-like body be-